

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
25 May 2001 (25.05.2001)

PCT

(10) International Publication Number
WO 01/37481 A2

(51) International Patent Classification⁷: H04L 12/00

(21) International Application Number: PCT/US00/30124

(22) International Filing Date:
9 November 2000 (09.11.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/164,956 12 November 1999 (12.11.1999) US

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(81) Designated States (national): AE, AL, AM, AT, AU, AZ,
BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK,
DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL,
IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU,
LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT,
RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA,
UG, US, UZ, VN, YU, ZA, ZW.

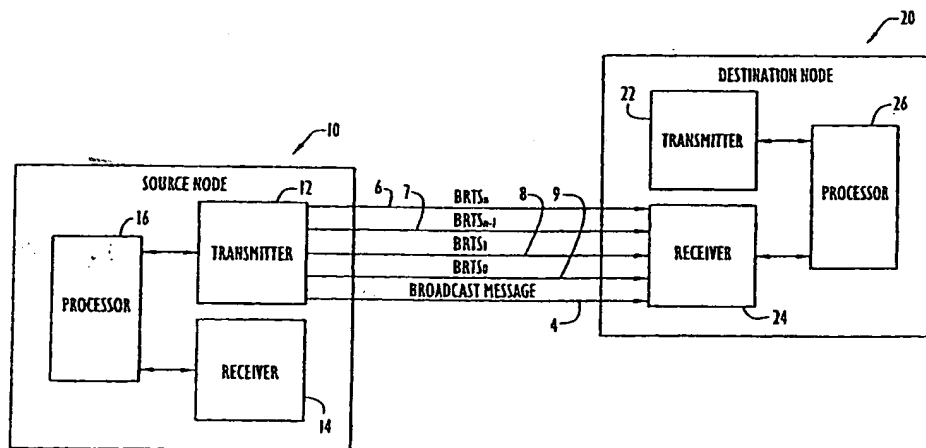
(84) Designated States (regional): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian
patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European
patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,
IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF,
CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

— Without international search report and to be republished
upon receipt of that report.

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND APPARATUS FOR BROADCASTING MESSAGES IN CHANNEL RESERVATION COMMUNICA-
TION SYSTEMS



(57) Abstract: A method and apparatus for broadcasting messages in accordance with the present invention transmits a broadcast message within a wireless communication system or network via utilization of redundant Request-to-Send type or broadcast notice messages or packets (BRTS). A source node repeatedly transmits a sequence of these messages over a system reservation channel with each message containing a sequence identifier. The sequence identifier of each succeeding message has a value immediately preceding the identifier of the previously transmitted broadcast notice message. A destination node receives the messages and determines the transmission time of the broadcast message based on each received message identifier. Subsequent transmission and reception of the final broadcast notice message in the sequence, the broadcast message is transmitted by the source node to the destination node over a data channel identified in the transmitted messages. The quantity of broadcast notice messages may be dynamically adjusted to maintain system performance at a desired level.

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METHOD AND APPARATUS FOR BROADCASTING MESSAGES IN CHANNEL RESERVATION COMMUNICATION SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. Provisional Patent Application Serial No. 60/164,956, entitled "Broadcast Method in Channel Reservation System and Apparatus" and filed November 12, 1999. The disclosure of that provisional application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention pertains to communication systems. In particular, the present invention pertains to a channel reservation communication system employing reliable transmission of broadcast messages (e.g., messages transmitted from a system source node to plural destination nodes within the system).

2. Discussion of Related Art

Generally, wireless communication systems or networks employ radio channels that are shared by each radio node within a system. However, simultaneous transmission of messages by radio nodes over the same radio channel produces collisions that degrade system performance. These collisions basically prevent reception of messages by the nodes, thereby causing the messages to be dropped and/or re-transmitted. Various conventional channel access schemes or protocols may be employed by a communication system to reduce the occurrence of collisions, such as Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), Time Division Multiple Access (TDMA) and channel reservation.

With respect to channel reservation, these types of schemes are typically employed by wireless communication systems to enhance reliability of packet transmissions. Basically, channel reservation schemes utilize one or more channels for transferring data and an additional independent channel for transference of reservation control information (e.g., information to reserve a data channel for transference of the data), and typically conduct a two-way handshake to initiate the data transference. In particular, a source node communications device, such as a modem, initially reserves a data channel for transmission

1 of a data packet in response to the data packet being received from a succeeding layer of a
2 communications protocol employed by the system. Communications protocols typically
3 include hierarchical layers with each layer having a specific function that, in combination,
4 receive, process and transmit messages. The layer functions may range from packet
5 generation and processing to physical or hardware functions of facilitating communications
6 across the network. Channel reservation is accomplished by the source node transmitting a
7 Request-to-Send (RTS) packet to an intended destination node over the reservation channel
8 in response to detecting available data channel space. The RTS packet generally includes
9 information that informs the destination node of a pending data packet and permits the
10 destination node to determine the presence of sufficient available data channel space for the
11 source node to transmit that packet. If the destination node detects sufficient available channel
12 space for transmission of the pending data packet, a Clear-to-Send (CTS) packet is transmitted
13 over the reservation channel from the destination node to the source node and includes
14 appropriate information to enable reservation of the data channel space for transmission of
15 the data packet. Once the source node receives the CTS packet, the data packet is transmitted
16 from the source node to the destination node over the reserved data channel space. Since the
17 destination node determines appropriate conditions for transmission of data packets, the
18 probability of collisions due to "hidden terminals" (e.g., nodes that simultaneously transmit
19 messages to a common destination node without being aware of the other transmissions,
20 thereby causing collisions at the common destination node) is minimized.

21 The channel reservation technique described above typically enhances
22 communications for point-to-point messages (e.g., messages that are directed from a source
23 node to one specific destination node). However, with respect to transmission of broadcast
24 messages (e.g., messages transferred from one source node to plural destination nodes), this
25 technique suffers from several disadvantages. In particular, the identities of intended
26 destination nodes for a broadcast message are typically unknown to a source node (e.g., at the
27 physical layer of the communications protocol where messages are transferred onto the
28 network), thereby imposing a substantial barrier for addressing and transmitting RTS packets
29 to different destination nodes. Further, even if destination nodes for a broadcast message are
30 identified by a source node, a substantial quantity of CTS messages are sent by the destination
31 nodes over the reservation channel in response to receiving an RTS packet, thereby causing

1 collisions in the reservation channel and reducing the success rate of reserving suitable data
2 channel space.

3 Since broadcast messages cannot be efficiently transmitted utilizing conventional
4 channel reservation schemes as described above, different techniques may be more suitable
5 for handling those types of messages. For example, one approach may include transmitting
6 the broadcast message via a modified channel reservation scheme. In particular, a source
7 node initially transmits an RTS message over a reservation channel to all nodes within the
8 source node transmission range. Once the RTS message is received, the destination nodes
9 wait for transmission of the broadcast message over a data channel identified in the RTS
10 packet, while the source node waits for expiration of a predetermined time interval. When the
11 time interval expires, the source node transmits the broadcast message over the identified data
12 channel.

13 The above-described techniques suffer from several disadvantages. In particular, the
14 techniques described above generally do not provide reliable broadcast communications and
15 adversely affect channel conditions. Since channel space for transmission of broadcast
16 messages cannot be securely reserved, transmission of these messages causes collisions in the
17 data channel when there is transmission of other data packets. Although collisions within the
18 data channel are infrequent when employing the channel reservation techniques described
19 above with a low or light traffic load, the frequency of collisions with these techniques
20 increases with heavier traffic loads, thereby causing re-transmission of point-to-point
21 messages and congestion of the data channels. Thus, performance of the above-described
22 techniques depends upon the condition of the reservation and data channels. In other words,
23 these techniques enhance communications when channel use is low, but have poor
24 performance and degrade channel conditions when the channels are heavily utilized or
25 congested.

26 OBJECTS AND SUMMARY OF THE INVENTION

27 Accordingly, it is an object of the present invention to broadcast messages within a
28 communications system while minimizing performance degradation due to increased system
29 traffic.
30

1 It is another object of the present invention to enhance reliability of broadcast
2 transmissions within a communication system and maintain system performance at a desired
3 level.

4 Yet another object of the present invention is to utilize redundant Request-to-Send
5 type messages (BRTS) in a communication system to ensure reliability of broadcast
6 transmissions.

7 Still another object of the present invention is to dynamically adjust the quantity of
8 RTS type messages (BRTS) transmitted within a communication system to enhance reliability
9 of broadcast transmissions and control system performance.

10 The aforesaid objects may be achieved individually and/or in combination, and it is
11 not intended that the present invention be construed as requiring two or more of the objects
12 to be combined unless expressly required by the claims attached hereto.

13 According to the present invention, a broadcast message is transmitted within a
14 wireless communication system or network via utilization of redundant Request-to-Send type
15 or broadcast notice messages or packets (BRTS). A source node repeatedly transmits a
16 sequence of these messages over a system reservation channel with each message containing
17 a sequence identifier. The sequence identifier of each succeeding message has a value
18 immediately preceding the identifier of the previously transmitted broadcast notice message.
19 A destination node receives the messages and determines the transmission time of the
20 broadcast message based on each received message identifier. Subsequent transmission and
21 reception of the final broadcast notice message in the sequence, the broadcast message is
22 transmitted by the source node to the destination node over a data channel identified in the
23 transmitted messages. The quantity of broadcast notice messages may be dynamically
24 adjusted to maintain system performance at a desired level.

25 The present invention achieves a greater success rate for transmission of broadcast
26 messages than conventional techniques that provide limited channel reservation capability,
27 and has a system performance that degrades gracefully and to a lesser degree than those
28 techniques as the channels become congested. Further, the present invention achieves greater
29 transmission reliability, and by dynamically controlling parameters or the quantity of the
30 broadcast notice messages employed, provides a manner in which to maintain a pre-defined
31 success rate under dynamically changing conditions. In other words, transmission

1 performance of the present invention may be maintained as channels become congested by
2 dynamically adjusting parameters. The present invention basically utilizes redundant
3 broadcast notice messages to ensure broadcast transmission reliability, thereby enhancing
4 transmission performance and reducing reservation channel capacity. Since utilization of the
5 reservation channel is generally low, increase in reservation channel traffic due to the
6 redundant broadcast notice messages has a limited impact on the reservation channel.

7 The above and still further objects, features and advantages of the present invention
8 will become apparent upon consideration of the following detailed description of specific
9 embodiments thereof, particularly when taken in conjunction with the accompanying
10 drawings, wherein like reference numerals in the various figures are utilized to designate like
11 components.

12 BRIEF DESCRIPTION OF THE DRAWINGS

13
14 Fig. 1 is a block diagram of network nodes transmitting and receiving a broadcast
15 message in accordance with the present invention.

16 Fig. 2 is a graphical illustration of a time line for broadcasting a message according
17 to the present invention.

18 Fig. 3 is a graphical illustration of a timing diagram for transmission of a point-to-
19 point message.

20 Fig. 4 is a graphical illustration of the relationship between the rate of reservation
21 channel utilization and the quantity of transmitter/receiver node pairs for an exemplary
22 network.

23 Figs. 5A - 5B are procedural flow charts illustrating the manner in which a network
24 node transmits a broadcast message according to the present invention.

25 Figs. 6A - 6B are procedural flow charts illustrating the manner in which a network
26 node receives and processes a broadcast message according to the present invention.

27 Fig. 7 is a graphical illustration of the relationship between the probability of success
28 of transmitting a broadcast message and the quantity of broadcast notice messages (BRTS)
29 employed in accordance with the present invention.

1 Fig. 8 is a graphical illustration of the quantity of broadcast notice messages (BRTS)
2 required for various probabilities of idle channels to achieve particular probabilities of success
3 in accordance with the present invention.
4

5 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

6 The present invention is directed toward a system and method for enhancing reliability
7 in the transmission of broadcast messages. Exemplary wireless network nodes of the present
8 invention transmitting and receiving a broadcast message are illustrated in Fig. 1. Specifically,
9 a source node 10 transmits a broadcast message or packet 4 to a destination node 20. The
10 source node includes a transmitter 12, a receiver 14 and a processor 16. The processor is
11 preferably implemented by a conventional microprocessor or controller and controls node 10
12 to transmit and receive messages in accordance with communication protocols as described
13 below. The transmitter is preferably implemented by a conventional transmitter and transmits,
14 preferably in the form of radio frequency (RF) signals, messages received from the processor
15 in accordance with processor instructions. Receiver 14 is typically implemented by a
16 conventional receiver and is configured to receive signals transmitted by the transmitter of
17 another node (e.g., preferably in the form of radio frequency (RF) signals). The receiver
18 receives the transmitted signals and forwards the received signals to processor 16 for
19 processing. Destination node 20 is substantially similar to node 10 and includes a transmitter
20 22, a receiver 24 and a processor 26. The destination node transmitter, receiver and processor
21 are substantially similar to the transmitter, receiver and processor of source node 10 described
22 above.

23 Source node 10 transmits a broadcast message 4 to destination node 20 utilizing a
24 channel reservation type scheme. As described above, channel reservation type techniques
25 generally employ one or more channels for transmitting data and an additional independent
26 channel for transference of reservation control information (e.g., information to reserve a data
27 channel for transference of the data). Channel reservation typically includes a two-way
28 handshake process. For example, a source node initially reserves data channel space for
29 transmission of a data message or packet. This is accomplished by transmitting a Request-to-
30 Send (RTS) packet to an intended destination node over the reservation channel in response
31 to detecting available data channel space. The RTS packet generally includes information that

1 informs the destination node of the pending data packet and permits the destination node to
2 determine the presence of sufficient available data channel space for the source node to
3 transmit the packet. If the destination node determines that sufficient data channel space is
4 available, a Clear-to-Send (CTS) packet including appropriate information to enable
5 reservation of the data channel space is transmitted over the reservation channel from the
6 destination node to the source node. Once the source node receives the CTS packet, the data
7 packet is transmitted from the source node to the destination node via the reserved data
8 channel space. However, this technique is problematic for broadcast messages since the
9 destination nodes are usually not known, or if the destination nodes are known, collisions
10 within the reservation channel are created due to the transmission of numerous CTS messages
11 by intended destination nodes. These disadvantages degrade reliability of broadcast message
12 transmission and reception.

13 The present invention employs a channel reservation type scheme that enhances
14 reliability of transmission and reception of broadcast messages (e.g., messages transmitted
15 from a network node to plural destination network nodes) as illustrated in Figs. 1-2. Initially,
16 source node 10 desires to transmit broadcast message 4 to network nodes within range of the
17 source node transmitter, including destination node 20. The source node basically transmits
18 a pre-determined quantity or sequence of Request-to-Send type or broadcast notice message
19 or packets (BRTS). These packets each typically include a packet identifier, a data channel
20 for transmission of the broadcast message and other information to facilitate transmission and
21 reception of the broadcast message. Once the final broadcast notice packet in a sequence is
22 transmitted, the source node transmits the broadcast message over the data channel identified
23 in the broadcast notice packets. Thus, the actual interaction between a source node transmitter
24 and destination node receiver is limited. In particular, source node 10 receives a data packet
25 from an upper layer of a communications protocol (e.g., a Medium Access Control (MAC)
26 layer of a communications protocol Data Link Layer which basically transfers data across a
27 shared channel) implemented by processor 16. The source node transmits an initial BRTS
28 packet 6 having an identifier 'n' ($BRTS_n$) and subsequently waits a predetermined time
29 interval to transmit a succeeding BRTS packet 7 having an identifier 'n-1' ($BRTS_{n-1}$). Each
30 packet identifier is preferably in the form of an integer that represents the position of that
31 broadcast notice packet in the sequence prior to transmission of broadcast message 4. For

example, $BRTS_3$ indicates that three additional broadcast notice packets (e.g., $BRTS_2$, $BRTS_1$, and $BRTS_0$) are sent prior to transmission of broadcast message 4. The identifiers typically start at a predetermined integer 'n' and are decremented with each successive broadcast notice packet, where $BRTS_n$ represents an initial packet and $BRTS_0$ represents the final packet in the broadcast notice packet sequence. Thus, $BRTS$ packet 7 has an identifier 'n-1' that precedes the identifier 'n' of $BRTS$ packet 6 in the sequence, and the total quantity of broadcast notice packets within the sequence is 'n+1'. Each broadcast notice packet is associated with a transmission start time, t_i , and a reception time, t'_i , where 'i' represents the packet identifier of a broadcast notice packet within a transmission sequence. The time interval, T_i , between transmission of succeeding broadcast notice packets in a sequence (e.g., the interval between reception of a broadcast notice packet having identifier 'i+1' and transmission of a broadcast notice message having identifier 'i') may be represented as follows:

$$T_i = \begin{cases} 0 & i=n \\ t_i - t'_{i+1} & i=n-1 \dots 0 \end{cases}$$

where 'n' represents the identifier of an initial packet within the broadcast notice packet sequence. Thus, the initial transmission packet does not have a delay, while the transmission interval for subsequent broadcast notice packets is determined from the difference between the transmission time of a current packet and the reception time of a prior packet.

Broadcast notice packets are transmitted in sequence at the appropriate transmission times, t_i , until a final packet 9 in the sequence ($BRTS_0$) has been sent. After the final broadcast notice packet is transmitted, the source node transmits broadcast message 4. The broadcast message should be received by time t''_E , while time T''_E represents the expected time interval to completion of the transmission process after the final broadcast notice packet is received at time t'_0 . This interval may be represented as $T''_E = t''_E - t'_0$. The broadcast notice packets are transmitted over the reservation channel in sequence prior to transmission of the broadcast message, while the broadcast message is transmitted in a pre-selected data channel indicated within those packets. The broadcast notice packets enhance the probability of detection by destination nodes of the scheduled broadcast message transmission.

In operation, the time interval between transmissions of broadcast notice packets, T_i , and the expected interval time to completion after reception of the final broadcast notice

packet in the sequence, T''_E , are predefined constants. Accordingly, if a broadcast notice packet having an identifier 'm' ($BRTS_m$; where 'm' is generally in the form of an integer and greater than or equal to zero) is received at a time, t_x , the estimated time for the source node transmitting that packet to transmit the final broadcast notice packet in the sequence may be determined as follows:

$$t_o = \begin{cases} t_x - T'_{RTS} & m=0 \\ t_x + (m-1) T'_{RTS} + \sum_{i=0}^{m-1} T_i & m>0; \end{cases} \quad (1)$$

where T'_{RTS} is the time interval between the start of transmission of a broadcast notice packet at a source node and completion of reception of that packet at a destination node. In other words, T'_{RTS} is typically known and may be expressed mathematically as $T'_{RTS} = t'_i - t_i$.

The time for reception of the broadcast message, t''_E , may be determined from the transmission time of the final broadcast notice packet, the interval between transmission and reception of that packet, and the expected time interval to completion, T''_E , as follows:

$$t''_E = t_o + T'_{RTS} + T''_E \quad (2)$$

Substituting the expressions for t_o from equation (1) into equation (2), the reception time for a broadcast message by a destination node, t''_E , may be determined as follows:

$$t''_E = \begin{cases} t_x + T''_E & m=0 \\ t_x + mT'_{RTS} + T''_E + \sum_{i=0}^{m-1} T_i & m>0. \end{cases} \quad (3)$$

As discussed above, the transmission interval between broadcast notice packets, T_i , and the interval between transmission of the broadcast notice packet in a sequence and reception of the broadcast message, T''_E , are pre-defined. Thus, the transmission and propagation intervals of a broadcast notice packet are known. Accordingly, a destination node may determine the transmission time, t_o , of a final broadcast notice packet from equation (1) above based on the broadcast notice packet identifier and the known values of T'_{RTS} , T_i , and the reception time, t_x , of the broadcast notice packet. The destination node may further apply the determined t_o value and the known T'_{RTS} and T''_E values to equation (2) above and predict the scheduled transmission time of a broadcast message. Since the destination node is aware of the transmission time of the broadcast message, that message is received unless the

1 destination node somehow misses all of the transmitted broadcast notice packets in a
 2 sequence. This occurrence is infrequent and unlikely, thereby enhancing reliability of the
 3 broadcast message. Further, since reception of the broadcast message is enhanced, occurrence
 4 of collisions within the data channel utilized for transmission of the broadcast message is
 5 similarly reduced.

6 Basically, the above broadcast transmission protocol sacrifices reservation channel
 7 capacity to achieve enhanced transmission performance. This trade-off is feasible since the
 8 reservation channel typically has a low utilization rate as illustrated in Fig. 3 by an exemplary
 9 network employing a conventional channel reservation protocol as described above to
 10 transmit point-to-point messages. In particular, a network source node initially transmits to
 11 a particular destination node a Request-to-Send (RTS) packet 30 on a reservation channel to
 12 indicate that a point-to-point message 34 is to be sent. The destination node receives the RTS
 13 packet and responds with a Clear-to-Send (CTS) packet 32 over the reservation channel to
 14 reserve a particular data channel and indicate that the message may be transmitted as
 15 described above. Message 34 and an acknowledgment 36 are subsequently sent to the
 16 destination node via the reserved data channel. The above data transference occurs within
 17 each transmission cycle and is exemplary of a maximum channel utilization rate. By way of
 18 example only: the network RTS, CTS and acknowledgment packets each include forty-six
 19 bits; the message includes 2,048 bits; the data channels may be used continuously for
 20 transmission of the messages; and there is no propagation delay for message transmissions.

21 As discussed above, an RTS and CTS packet are transmitted over the reservation
 22 channel with an acknowledgment packet sent over the data channel for each transmitted point-
 23 to-point message. Therefore, 2,094 bits (e.g., 2,048 bits for the message and forty-six bits for
 24 the acknowledgment) are transmitted over the data channel, while ninety-two bits (e.g., forty-
 25 six bits for each of the RTS and CTS packets) are transmitted over the reservation channel.
 26 Since the transmission cycle is repeated without propagation delay, the utilization rate of the
 27 reservation channel when one channel is employed for packet transmission is:

$$\begin{array}{lcl} \text{RTS packet + CTS packet} & = & \frac{46 + 46}{2048 + 46} = 4.39\% \\ \text{Message + Acknowledgment} & & \end{array}$$

31 Thus, the reservation channel utilization rate under normal conditions should be less than
 32 4.39% when one source node/destination node pair is employed. However, if 'P' node pairs

1 (e.g., where P is greater than one) within radio range engage in simultaneous message
2 transmissions, the reservation channel utilization upper limit is 4.39% multiplied by ' P '
3 (e.g., 4.39 P %). A plot of the relationship between the reservation channel utilization upper
4 limit and quantity of node pairs engaged in simultaneous message transmissions is illustrated
5 in Fig. 4.

6 When the exemplary network employs two data channels, simultaneous message
7 transmissions may occur. For example, if the exemplary network included ten nodes or five
8 node pairs (e.g., ' P ' equal to five) within radio range, the upper limit of reservation channel
9 utilization is 4.39% multiplied by five, or 21.95%. Since the network nodes require special
10 positioning to enable power control functionality and the channel reservation scheme to
11 accommodate channel reservation and simultaneous transmissions by such nodes, it is
12 unlikely that this quantity of nodes would conduct simultaneous transmissions within the
13 exemplary network. Thus, for normal operating conditions, the reservation channel utilization
14 of the network should not be greater than 21.95%, thereby indicating low utilization of the
15 reservation channel. Since the reservation channel has a low utilization rate, and since
16 broadcast traffic in a wireless network typically occupies a low percentage of the overall
17 network traffic, the increased traffic load in the reservation channel by the present invention
18 has a limited and minimal effect on the condition of the reservation channel.

19 Each present invention node within a network may function as a source node and
20 destination node to transmit and receive broadcast messages. The processor within each node
21 controls the node to transmit and receive broadcast messages in accordance with the plural
22 broadcast notice packet scheme described above. Receiving and transmission processes or
23 state machines are executed by the processor in parallel with each associated with a particular
24 broadcast message and functioning as an independent process to facilitate handling of
25 transmission and reception of that message. Each receiving process further identifies its
26 associated broadcast message to facilitate handling of messages received by different plural
27 source nodes. The manner in which a node processor controls a node to transmit point-to-
28 point and broadcast messages according to the present invention is illustrated in Fig. 5A.
29 Initially, a transmitting process or state machine is created within the node processor and
30 executed when a broadcast message is received from an upper layer of a communications
31 protocol employed by the network and implemented by the processor. Specifically, a

1 message is received from an upper layer of the communications protocol at step 40 (e.g., the
2 MAC Layer of a protocol Data Link Layer as described above). If the message is a point-to-
3 point message as determined at step 42, the processor determines the existence of a broadcast
4 transmission process at step 44. When a broadcast transmission process exists and
5 transmission of the point-to-point message may be accomplished prior to transmission of a
6 final broadcast notice packet (BRTS_o) of the existing process as determined at step 45,
7 transmission of the point-to-point message to the intended destination node is initiated (e.g.,
8 an RTS packet is transmitted) at step 46. The processor basically calculates the transmission
9 time, t_o , of the final broadcast notice packet within the transmission sequence from the
10 aforementioned equations as described above in order to determine the feasibility of
11 completing transmission of the point-to-point message prior to that packet transmission time.
12 Transmission of the point-to-point message is further initiated at step 46 when the processor
13 determines at step 44 that no broadcast transmission processes exist. If the point-to-point
14 message can not be transmitted prior to transmission of the final broadcast notice packet, the
15 message is stored in a buffer for subsequent transmission at step 50.

16 If the message received from the upper protocol layer is a broadcast message as
17 determined at step 42, the processor determines at step 48 the existence of broadcast receiving
18 or transmission processes. If either of these processes exist, the broadcast message is saved
19 in a buffer for subsequent transmission at step 50. When no broadcast processes exist, a new
20 process or state machine is created for the received message and a counter for the broadcast
21 notice packets is initialized to the initial packet identifier (e.g., 'n', typically in the form of
22 an integer greater than zero) at step 52. A transmission timer is set at step 54 to expire at time,
23 t_o , or the transmission time of a broadcast notice packet (e.g., having an identifier 'i'
24 commensurate with the value of the packet counter). The processor waits for expiration of
25 the timer at step 56, and subsequently controls the transmitter to transmit the broadcast notice
26 packet at step 58. After transmission of that packet, the packet counter is decremented at step
27 60 and typically provides the packet identifier for the succeeding broadcast notice packet. If
28 the counter has a value greater than zero as determined at step 62, thereby indicating that
29 transmission of a final broadcast notice packet (BRTS_o) has not occurred, the transmission
30 timer is re-set at step 54 and subsequent broadcast notice packets within the sequence (e.g.,
31 having packet identifiers 'i' commensurate with the packet counter value) are transmitted as

1 described above. When the counter attains a value less than zero as determined at step 62, the
2 final broadcast notice packet has been transmitted and a broadcast timer is initialized for
3 transmission of a broadcast message at step 64. The processor waits for expiration of the
4 broadcast timer at step 66, and subsequently controls the transmitter to transmit the broadcast
5 message at step 68. If additional messages (e.g., new messages or messages stored in the
6 buffer) require processing as determined at step 70, the messages are processed as described
7 above.

8 The processor may further handle various messages that are received by the node
9 during a broadcast transmission process as illustrated in Fig. 5B. Specifically, a message is
10 received by the node at step 80. If the received message is a broadcast notice packet for a
11 broadcast message as determined at step 82, the processor determines the existence of a
12 corresponding process or state machine to handle that message at step 84. When a process for
13 the broadcast notice packet does not exist, a new process is created to handle that packet at
14 step 86. Otherwise, the received packet is forwarded at step 88 to the corresponding existing
15 process for event handling as described below.

16 When the received message is identified as an RTS packet for a point-to-point
17 message at step 90, the processor determines the existence of a broadcast transmission process
18 at step 92. If a transmission process exists and the point-to-point message may be received
19 prior to transmission of a final broadcast notice packet as determined at step 94, a reply or
20 CTS packet is transmitted at step 96 to facilitate transmission and reception of the point-to-
21 point message. The processor basically calculates the transmission time, t_o , of the final
22 broadcast notice packet from the aforementioned equations as described above to determine
23 the feasibility of completing reception of the point-to-point message prior to that packet
24 transmission time. The reply is further transmitted at step 96 in response to the processor
25 determining that no transmitting processes exist at step 94. When the point-to-point message
26 can not be received prior to transmission of a final broadcast notice packet for an existing
27 transmission process as determined at step 94, the received RTS packet is dropped at step 98.

28 When the received message is a point-to-point CTS packet as determined at step 100,
29 the processor determines the existence of a broadcast transmission process at step 102. If a
30 process exists and the point-to-point message may be transmitted prior to transmission of a
31 final broadcast notice packet for the existing process as determined at step 104, the pending

1 point-to-point message is transmitted at step 106. The processor basically calculates the final
2 broadcast notice packet transmission time from the aforementioned equations as described
3 above to determine the feasibility of transmitting the point-to-point message prior to the final
4 broadcast notice packet transmission time. The point-to-point message is further transmitted
5 at step 106 in response to the processor determining that no transmitting processes exist at
6 step 102. When the point-to-point message can not be transmitted prior to transmission of a
7 final broadcast notice packet of an existing transmission process as determined at step 104,
8 the CTS packet is ignored and the pending point-to-point message is stored in a buffer for
9 subsequent transmission at step 108.

10 When the received message is identified as a point-to-point message at step 110, an
11 acknowledgment is transmitted to the source node at step 112. If additional messages require
12 processing (e.g., new messages or messages stored in the buffer) as determined at step 114,
13 the messages are processed as described above. The above processing scheme of Figs. 5A-5B
14 allows transmission and reception of point-to-point messages in a manner that efficiently
15 utilizes channel space during execution of a broadcast transmission process. However, no
16 transmission of a broadcast message is initiated during execution of a broadcast transmission
17 or receiving process in order to reduce traffic load on the reservation channel.

18 The manner in which a node processor controls the node to receive a broadcast
19 message is illustrated in Fig. 6A. Initially, a receiving process or state machine is created in
20 response to receiving an initial broadcast notice packet from a source node prior to
21 transmission of the associated broadcast message. Specifically, a broadcast notice packet is
22 received from a new source node at step 120 and a receiving process or state machine is
23 created for the associated broadcast message. If a broadcast transmission process is executing
24 as determined at step 122, the processor at step 124 determines whether or not the
25 transmission process can transmit a broadcast message prior to reception of the broadcast
26 message associated with the received broadcast notice packet. The transmission and reception
27 times of the respective broadcast messages are determined from the respective packet
28 identifiers and the aforementioned equations as described above. Alternatively, the identifiers
29 of the respective packets may be compared to determine the earlier of the transmission or
30 reception time. Basically, the packet having an identifier with a lesser value indicates the
31 associated message having an earlier transmission or reception time. When reception of the

1 broadcast message associated with the received packet is determined to occur prior to
2 transmission of the broadcast message associated with the executing transmission process,
3 the transmission process is interrupted and the associated broadcast message is stored in a
4 buffer at step 126 for subsequent transmission after reception of the message associated with
5 the received packet. When a broadcast transmission process is not executing as determined
6 at step 122, or when reception of the message associated with the received packet occurs after
7 transmission by the executing broadcast process as determined at step 124, the node
8 determines the transmission time, t_o , of the final broadcast notice packet in the sequence
9 associated with the received packet and the estimated time of completion of the reception
10 process, t''_E , from the aforementioned equations as described above, and sets a reception
11 timer for the expected reception time of the message, t''_E , at step 132. This determination and
12 timer initialization are similarly performed subsequent to message storage at step 126. The
13 reception time is utilized by the receiver in order to direct the node to the appropriate data
14 channel at a proper time to receive the broadcast message. Subsequently, the node waits at
15 step 136 for the reception time of the next broadcast notice packet in the sequence or the
16 broadcast message. Since network or other conditions may affect transmission and reception
17 of broadcast notice packets, a broadcast message may be received by the node without prior
18 reception of each broadcast notice packet in a sequence. Thus, the node identifies reception
19 of a broadcast message that may be received out of sequence relative to the broadcast notice
20 packets.

21 When the broadcast notice packet is received as determined at step 138, that packet
22 is processed as described above. If the broadcast message is received as determined at step
23 144, the reception timer is canceled at step 146. The node basically waits for a broadcast
24 notice packet or the broadcast message until expiration of the reception timer or, in other
25 words, until the expected reception time of the broadcast message has elapsed as determined
26 at step 140. If additional messages or packets (e.g., received from a new source node or stored
27 in the buffer) require processing as determined at step 150, the messages or packets are
28 processed as described above.

29 The processor may further handle various messages that are received or generated by
30 the node during the receiving process as illustrated in Fig. 6B. Specifically, a message is
31 received by a node at step 160. If the message is a broadcast message received from a

1 communications protocol upper layer (e.g., the MAC Layer as described above) for
2 transmission by the node as determined at step 162, the processor determines the existence
3 of an executing broadcast transmission or receiving process at step 164. When a broadcast
4 process is executing, the broadcast message is stored in a buffer for subsequent transmission
5 at step 174. Otherwise, the message is processed for transmission at step 166 in the manner
6 described above for Fig. 5A. This reduces the quantity of broadcast notice packets being
7 transmitted in the reservation channel.

8 When the received message is a point-to-point message received from a
9 communications protocol upper layer (e.g., the MAC Layer as described above) for
10 transmission as determined at step 168, the processor determines the time interval available
11 before the transmission time, t_o , of a final broadcast notice packet for each broadcast message
12 receiving process. This is typically accomplished by examining identifiers of recently
13 received broadcast notice packets and determining the time based on the aforementioned
14 equations as described above. If the point-to-point message can be transmitted prior to the
15 earliest time, t_o , for the existing broadcast receiving processes as determined at step 170,
16 transmission of the received point-to-point message is initiated (e.g., an RTS packet is
17 transmitted) at step 172. Otherwise, the point-to-point message is stored in a buffer for
18 subsequent transmission at step 174. The messages stored in the buffer are transmitted after
19 completion of the receiving process as described above.

20 If the received message is an RTS packet for a point-to-point message as determined
21 at step 176, the processor determines the existence of a broadcast receiving process at step
22 178. If a broadcast receiving process exists, the processor determines the time interval
23 available before the transmission time, t_o , of a final broadcast notice packet for each existing
24 broadcast receiving process as described above. If the point-to-point message may be
25 received prior to the earliest final packet transmission time, t_o , of the existing broadcast
26 receiving processes, a reply or CTS packet is transmitted at step 182 to facilitate transmission
27 and reception of the point-to-point message. The reply is further transmitted at step 182 in
28 response to the processor determining that no broadcast receiving process exists at step 178.
29 When the point-to-point message can not be received prior to the earliest final packet
30 transmission time as determined at step 180, the RTS packet is dropped at step 184.

1 When the received message is a point-to-point CTS packet as determined at step 186,
2 the processor determines the existence of a broadcast receiving process at step 188. If a
3 broadcast receiving process exists, the processor determines the time interval available before
4 the transmission time, t_o , of a final broadcast notice packet for each existing broadcast
5 receiving process as described above. If the point-to-point message may be transmitted prior
6 to the earliest final packet transmission time, t_o , of the existing broadcast receiving processes
7 as determined at step 190, the point-to-point message is transmitted at step 192. The point-to-
8 point message is further transmitted at step 192 in response to the processor determining that
9 no broadcast receiving process exists at step 188. When the point-to-point message can not
10 be transmitted prior to the earliest final transmission time as determined at step 190, the CTS
11 packet is ignored and the point-to-point message is stored in a buffer for subsequent
12 transmission at step 194.

13 If the received message is a point-to-point message as determined at step 196, an
14 acknowledgment is transmitted to the source node at step 198.

15 When the received message is a broadcast notice packet (BRTS) as determined at step
16 200, the processor determines the existence of a corresponding broadcast receiving process
17 at step 202. If a broadcast receiving process associated with the received packet does not
18 exist, a new process is created at step 204; otherwise, the received packet is forwarded to the
19 corresponding process at step 206. The received packet is subsequently processed in
20 substantially the same manner described above for Fig. 6A. If additional messages require
21 processing (e.g., new messages or messages stored in the buffer) as determined at step 208,
22 the messages are processed as described above. The above processing scheme of Figs. 6A-6B
23 allows transmission and reception of point-to-point messages in a manner that efficiently
24 utilizes channel space during execution of a broadcast receiving process. However, no
25 transmission of a broadcast message is initiated during execution of a broadcast transmission
26 or receiving process in order to reduce traffic load on the reservation channel. The various
27 received packets (e.g., RTS, BRTS, CTS, etc.) typically include an identifier to indicate the
28 type of message (e.g., broadcast or point-to-point) being sent.

29 As discussed above, a destination node fails to receive a broadcast message only in
30 the event that all broadcast notice packets are missed. Since plural broadcast notice packets
31 are used to indicate transmission of a pending broadcast message, the probability of failing

to receive the broadcast notice packets should decrease as the quantity of broadcast notice packets employed by the scheme increases. For example, and with reference to the exemplary network described above for Figs. 3-4, P_{idle} represents the probability that all channels are idle, while $P_{idle,j}$ represents the probability of a channel being idle from the perspective of a node. Accordingly,

$$P_{idle} = \prod_{j=0}^{r-2} P_{idle,j} \quad (4)$$

where 'j' is in the form of an integer generally greater than or equal to one and represents a channel; 'r' is in the form of an integer and represents the quantity of channels; and the exemplary network includes two channels (e.g., 'r' equals two) as described above. Further, P_{succ} represents the probability of successfully transmitting a broadcast message employing the scheme of the present invention, and from equation (4) above may be defined as follows:

$$P_{succ} = 1 - (1 - P_{idle})^{k+1} = 1 - (1 - \prod_{j=0}^{r-2} P_{idle,j})^{k+1} \quad (5)$$

where k is in the form of an integer generally greater than or equal to zero and indicates the quantity of broadcast notice packets employed (e.g., $k = n + 1$ with respect to Fig. 2). A plot of the relationship between P_{succ} and the quantity of broadcast notice packets (k) employed for various values of P_{idle} is illustrated in Fig. 7. The plot indicates that for a fixed value of P_{idle} , the value of P_{succ} increases as the quantity of broadcast notice packets increases. In fact, the value of P_{succ} may be controlled by adjusting the quantity of broadcast notice packets according to the relationship defined in equation (5) above. Thus, a desirable transmission performance may be maintained by employing an appropriate quantity of broadcast notice packets in the scheme of the present invention.

Accordingly, the present invention may be employed in an adaptive configuration to achieve a desired performance. Basically, the present invention may vary the quantity of broadcast notice packets utilized within each broadcast transmission process according to the condition of the channels. In other words, a greater quantity of broadcast notice packets are employed when channels are heavily utilized, while a lesser quantity is employed for low channel utilization. The quantity of broadcast notice packets (k) may be derived from equation (5) above and is determined as follows:

$$k = \left\lceil \frac{\log(1 - P_{\text{succ}}) - 1}{\log(1 - P_{\text{idle}})} \right\rceil = \left\lceil \frac{\log(1 - P_{\text{succ}}) - 1}{\log(1 - \prod_{j=0}^{r-2} P_{\text{idle},j})} \right\rceil \quad (6)$$

where the brackets (' $\lceil \rceil$ ') indicate an operator that provides an integer larger than or equal to the enclosed value. A plot of the quantity of broadcast notice packets required to maintain particular P_{succ} values (e.g., 0.99, 0.95, 0.9 and 0.85) for various probabilities of idle channels is illustrated in Fig. 8. If the value of P_{idle} is known when a broadcast transmission process is initiated, the value of P_{succ} may be maintained at a desirable level by using the appropriate quantity of broadcast notice packets. Since P_{idle} is typically unknown, a conventional adaptive estimation technique may be utilized to determine the values of P_{idle} or $P_{\text{idle},j}$, thereby enabling dynamic determination of the quantity of broadcast notice packets (k) to employ from equation (6) above. Thus, this dynamic determination enables maintaining performance of the scheme at a pre-defined or desired success level.

The transmission processes within node processors may dynamically determine the quantity of broadcast notice packets to transmit prior to sending a broadcast message. Since each broadcast notice packet includes an identifier indicating a position of that packet within a sequence as described above, the packet quantity may be altered by the source node without affecting the processing by a destination node. In other words, the destination node determines the message reception time based on the received identifier as described above, and receives the message at the appropriate time regardless of the value or change in the packet quantity. Basically, the destination node determines a reception time based on the most recently received packet identifier.

The present invention enables messages to be broadcasted across a communication network having any quantity of nodes, where the network nodes are substantially similar to each other and to source node 10 and destination node 20 described above for Fig. 1. Each network node receiving a broadcast message typically transmits that message in the manner described above to its neighbors to facilitate propagation of the message through the network.

It will be appreciated that the embodiments described above and illustrated in the drawings represent only a few of the many ways of implementing a method and apparatus for broadcasting messages in channel reservation communication systems.

1 The communication networks employing the present invention nodes may include any
2 quantity of those nodes. The nodes may communicate via any suitable communications
3 medium (e.g., wired or wireless communication devices, etc.) and utilize any quantities of
4 reservation and data channels. The present invention node may include any quantity of
5 conventional or other transmitters, where each transmitter may transmit signals at any suitable
6 frequency and in any suitable energy form (e.g., radio signals, microwave, optical signals,
7 etc.), and any quantity of conventional or other receivers, where each receiver may receive
8 signals at any suitable frequency and in any suitable energy form (e.g., radio signals,
9 microwave, optical signals, etc.). Alternatively, the present invention node may include any
10 quantity of combined transmitting/receiving devices.

11 The processor of the present invention node may be implemented by any conventional
12 or other microprocessor, controller or circuitry to perform the functions described herein,
13 while any quantity of processors or processing devices or circuitry may be employed within
14 the present invention node where the processor functions may be distributed in any fashion
15 among any quantity of modules, processors or other processing devices or circuits. The
16 software for the processor of the present invention node may be implemented in any suitable
17 computer language, and could be developed by one of ordinary skill in the computer and/or
18 programming arts based on the functional description contained herein and the flow charts
19 illustrated in the drawings. Further, any references herein of software performing various
20 functions generally refer to processors performing those functions under software control.
21 The software and/or algorithms described above and illustrated in the flow charts may be
22 modified in any manner that accomplishes the functions described herein.

23 The broadcast notice (BRTS) and other packets or messages (e.g., RTS, CTS,
24 acknowledge, point-to-point message, broadcast message, etc.) may be of any size, may have
25 any format, and may contain any desired information. Further, the various messages may
26 include any identifier to identify the type of message or packet. The communication network
27 may employ any suitable communications protocol to facilitate reception, processing and
28 transference of messages or packets. The present invention may send any quantity of
29 broadcast notice packets at any desired transmission intervals prior to transmission of the
30 broadcast message. The broadcast notice packet identifiers may be any numeric value,
31 alphanumeric character or other symbol, preferably having a known or assignable position

1 within an associated identifier sequence. The broadcast notice packets may be transmitted
2 in any suitable order capable of identifying a transmission time of a final broadcast notice
3 packet or broadcast message. The present invention node may prioritize processing of
4 broadcast, point-to-point or other messages in any fashion. The buffer may be implemented
5 by any suitable storage device (e.g., processor memory, external memory, file, data structure
6 (e.g., array, queue, stack, etc.), etc.) to store messages for subsequent processing.

7 The present invention may utilize any quantity of broadcast notice packets, where the
8 quantity may be predetermined and fixed or dynamically adjusted to any desired value. The
9 adjustment may be based on any network conditions or other desired parameters. For
10 example, the quantity may be altered based on channel utilization or network traffic or to
11 maintain a particular network performance level. The probability of idle channels may be
12 estimated utilizing any conventional or other techniques to determine the appropriate quantity
13 of broadcast notice packets for a particular performance level. The above equations may be
14 modified in any manner, or any conventional or other techniques may be employed by the
15 present invention to determine the quantity of broadcast notice packets to transmit and the
16 transmission and reception times of broadcast packets or messages. Further, the processor of
17 the present invention node may determine transmission and reception times of point-to-point
18 and other messages via any conventional or other techniques.

19 It is to be understood that the present invention is not limited to the applications or
20 networks described herein, but may be utilized for various communication applications or
21 networks, especially those employing channel reservation techniques. Since the present
22 invention does not employ hand-shaking with destination nodes (e.g., CTS packets are not
23 utilized), the present invention is suitable for applications where two-way hand shaking is not
24 feasible, such as one-to-multipoint messages (e.g., broadcast and multicast messages).
25 However, the present invention may further be applied to hand-shaking applications and for
26 any types of messages.

27 From the foregoing description, it will be appreciated that the invention makes
28 available a novel method and apparatus for broadcasting messages in channel reservation
29 communication systems wherein plural broadcast notice messages are transmitted prior to
30 transmission of the broadcast message.

1 Having described preferred embodiments of a new and improved method and
2 apparatus for broadcasting messages in channel reservation communication systems, it is
3 believed that other modifications, variations and changes will be suggested to those skilled
4 in the art in view of the teachings set forth herein. It is therefore to be understood that all such
5 variations, modifications and changes are believed to fall within the scope of the present
6 invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1 1. In a communications network, a communication unit to transmit and receive
2 messages within said network comprising:

3 a transmitter to transmit an outgoing message to at least one other communication
4 unit within said network;

5 a receiver to receive an incoming message from at least one other communication unit
6 within said network; and

7 a processor to control said transmission and reception of said outgoing and incoming
8 messages, wherein said processor includes:

9 a broadcast notification module to facilitate transmission of a plurality of
10 broadcast notification messages in a particular transmission sequence to said at least one other
11 communication unit, wherein said broadcast notification messages notify said at least one
12 other communication unit of a pending broadcast message; and

13 a broadcast transmission module to facilitate transmission of said pending
14 broadcast message to said at least one other communication unit subsequent to transmission
15 of said plurality of broadcast notification messages within said transmission sequence.

1 2. The unit of claim 1 wherein each said broadcast notification message includes
2 an identifier indicating a position of that notification message within said transmission
3 sequence.

1 3. The unit of claim 2 wherein said broadcast notification module includes a
2 transmission sequence module to facilitate transmission of each broadcast notification
3 message at a particular time interval and in accordance with said position of that notification
4 message within said transmission sequence indicated by said identifier associated with that
5 notification message.

1 4. The unit of claim 1 wherein said transmitter transmits said outgoing message
2 in the form of radio signals.

1 5. The unit of claim 1 wherein said receiver receives said incoming message in
2 the form of radio signals.

1 6. The unit of claim 2 wherein said processor further includes:
2 a notification reception module to facilitate reception of said broadcast notification
3 messages and to determine a reception time for said pending broadcast message based on said
4 identifier of each received broadcast notification message; and
5 a broadcast reception module to facilitate reception of said pending broadcast message
6 by said determined reception time.

1 7. The unit of claim 2 wherein said network includes a reservation channel for
2 conveyance of data channel reservation information and at least one data channel for
3 conveyance of data, and wherein said communication unit transmits said broadcast
4 notification messages over said reservation channel and transmits said pending broadcast
5 message over a data channel indicated in said transmitted broadcast notification messages.

1 8. The unit of claim 1 wherein said processor further includes a transmission
2 control module to store said pending broadcast message in a storage unit in response to said
3 communication unit transmitting or receiving another broadcast message.

1 9. The unit of claim 2 wherein said processor further includes a message control
2 module to prioritize transmission of said pending broadcast message with respect to other
3 messages received from said network, said message control module including:

4 a broadcast notification handler to generate a corresponding processor task to process
5 a broadcast notification message received from a new network source and to provide a
6 broadcast notification message received from said network and associated with an existing
7 processor task to that task to facilitate processing of said received broadcast notification
8 message;

9 a network message handler to process a network message associated with a network
10 message notification received from said network in response to determining that said

11 associated network message can be processed within an interval prior to transmission of said
12 pending broadcast message; and
13 a network message module to facilitate transmission of an acknowledgment in
14 response to receiving said associated network message from said network.

1 10. The unit of claim 2 wherein said processor further includes a message control
2 module to prioritize reception of a first broadcast message with respect to processing of other
3 messages, said message control module including:

4 a broadcast message handler to facilitate transmission of a second broadcast message
5 and to store said second broadcast message in a storage unit for subsequent transmission in
6 response to current processing for reception of said first broadcast message;

7 a broadcast notification handler to generate a corresponding processor task to process
8 a broadcast notification message received from a new network source and to provide a
9 broadcast notification message received from said network and associated with an existing
10 processor task to that task for processing of said received broadcast notification message;

11 a network message handler to process a network message associated with a message
12 notification received from said network in response to determining that said associated
13 network message can be processed within an interval prior to reception of each broadcast
14 message associated with a received broadcast notification message corresponding to an
15 existing processor task; and

16 a network message module to facilitate transmission of an acknowledgment in
17 response to receiving said associated network message from said network.

1 11. The unit of claim 6 wherein said notification reception module includes a
2 message control module to prioritize transmission and reception of broadcast messages, and
3 wherein said message control module includes a transmission interrupt module to interrupt
4 transmission of a first broadcast message and store said first broadcast message in a storage
5 unit for subsequent transmission in response to determining that a second broadcast message
6 associated with a broadcast notification message received from said network can be received
7 within an interval prior to transmission of said first broadcast message.

1 12. The unit of claim 1 wherein said processor further includes a message quantity
2 module to dynamically determine a quantity of broadcast notification messages to transmit
3 prior to transmission of said pending broadcast message based on network parameters.

1 13. In a communications network, a method of transmitting and receiving
2 broadcast messages within said network comprising the steps of:

3 (a) transmitting a plurality of broadcast notification messages in a particular
4 transmission sequence to at least one communication unit within said network, wherein said
5 broadcast notification messages notify said at least one communication unit of a pending
6 broadcast message; and

7 (b) transmitting said pending broadcast message to said at least one
8 communication unit subsequent to transmission of said plurality of broadcast notification
9 messages within said transmission sequence.

1 14. The method of claim 13 wherein each said broadcast notification message
2 includes an identifier indicating a position of that notification message within said
3 transmission sequence.

1 15. The method of claim 14 wherein step (a) further includes:

2 (a.1) transmitting each broadcast notification message at a particular time interval
3 and in accordance with said position of that notification message within said transmission
4 sequence indicated by said identifier associated with that notification message.

1 16. The method of claim 13 wherein said broadcast notification and broadcast
2 messages are transmitted in the form of radio signals.

1 17. The method of claim 14 further including the steps of:

2 (c) receiving said broadcast notification messages at said at least one
3 communication unit and determining a reception time for said pending broadcast message
4 based on said identifier of each received broadcast notification message; and

5 (d) receiving said pending broadcast message at said at least one communication
6 unit by said determined reception time.

1 18. The method of claim 17 wherein said broadcast notification and broadcast
2 messages are received in the form of radio signals.

1 19. The method of claim 14 wherein said network includes a reservation channel
2 for conveyance of data channel reservation information and at least one data channel for
3 conveyance of data, and wherein step (a) further includes:

4 (a.1) transmitting said broadcast notification messages over said reservation channel
5 and transmitting said pending broadcast message over a data channel indicated in said
6 transmitted broadcast notification messages.

1 20. The method of claim 13 wherein step (a) further includes:

2 (a.1) storing said pending broadcast message in a storage unit in response to
3 transmitting or receiving another broadcast message.

1 21. The method of claim 14 wherein step (a) further includes:

2 (a.1) prioritizing transmission of said pending broadcast message with respect to
3 other messages received from said network, wherein step (a.1) further includes:

4 (a.1.1) generating a corresponding processor task to process a broadcast
5 notification message received from a new network source and providing a broadcast
6 notification message received from said network and associated with an existing processor
7 task to that task to facilitate processing of said received broadcast notification message;

8 (a.1.2) processing a network message associated with a network message
9 notification received from said network in response to determining that said associated
10 network message can be processed within an interval prior to transmission of said pending
11 broadcast message; and

12 (a.1.3) transmitting an acknowledgment in response to receiving said
13 associated network message from said network.

- 1 22. The method of claim 17 wherein step (c) further includes:
2 (c.1) prioritizing reception of a first broadcast message with respect to processing
3 of other messages, wherein step (c.1) further includes:
4 (c.1.1) facilitating transmission of a second broadcast message and storing said
5 second broadcast message in a storage unit for subsequent transmission in response to current
6 processing for reception of said first broadcast message;
7 (c.1.2) generating a corresponding processor task to process a broadcast
8 notification message received from a new network source and providing a broadcast
9 notification message received from said network and associated with an existing processor
10 task to that task for processing of said received broadcast notification message;
11 (c.1.3) processing a network message associated with a message notification
12 received from said network in response to determining that said associated network message
13 can be processed within an interval prior to reception of each broadcast message associated
14 with a received broadcast notification message corresponding to an existing processor task;
15 and
16 (c.1.4) transmitting an acknowledgment in response to receiving said
17 associated network message from said network.

- 1 23. The method of claim 17 wherein step (c) further includes:
2 (c.1) prioritizing transmission and reception of broadcast messages, wherein step
3 (c.1) further includes:
4 (c.1.1) interrupting transmission of a first broadcast message and storing said
5 first broadcast message in a storage unit for subsequent transmission in response to
6 determining that a second broadcast message associated with a broadcast notification message
7 received from said network can be received within an interval prior to transmission of said
8 first broadcast message.

- 1 24. The method of claim 13 wherein step (a) further includes:
2 (a.1) dynamically determining a quantity of broadcast notification messages to
3 transmit prior to transmission of said pending broadcast message based on network
4 parameters.

1 25. In a communications network, a communication unit to transmit and receive
2 messages within said network comprising:

3 a transmitter to transmit an outgoing message to at least one other communication
4 unit within said network;

5 a receiver to receive an incoming message from at least one other communication unit
6 within said network; and

7 a processor to control said transmission and reception of said outgoing and incoming
8 messages, wherein said processor includes:

9 a notification module to facilitate transmission of a plurality of notification
10 messages in a particular transmission sequence to said at least one other communication unit,
11 wherein said notification messages notify said at least one other communication unit of a
12 pending message; and

13 a transmission module to facilitate transmission of said pending message to
14 said at least one other communication unit subsequent to transmission of said plurality of
15 notification messages within said transmission sequence.

1 26. The unit of claim 25 wherein each said notification message includes an
2 identifier indicating a position of that notification message within said transmission sequence.

1 27. The unit of claim 25 wherein said pending message is a broadcast message.

1 28. The unit of claim 26 wherein said processor further includes:

2 a notification reception module to facilitate reception of said notification messages and
3 to determine a reception time for said pending message based on said identifier of each
4 received notification message; and

5 a reception module to facilitate reception of said pending message by said determined
6 reception time.

1 29. In a communications network, a method of transmitting and receiving
2 messages comprising the steps of:

- 3 (a) transmitting a plurality of notification messages in a particular transmission
4 sequence to at least one communication unit within said network, wherein said notification
5 messages notify said at least one communication unit of a pending message; and
6 (b) transmitting said pending message to said at least one communication unit
7 subsequent to transmission of said plurality of notification messages within said transmission
8 sequence.

1 30. The method of claim 29 wherein each said notification message includes an
2 identifier indicating a position of that notification message within said transmission sequence.

1 31. The method of claim 29 wherein said pending message is a broadcast message.

1 32. The method of claim 30 further including the steps of:

- 2 (c) receiving said notification messages at said at least one communication unit
3 and determining a reception time for said pending message based on said identifier of each
4 received notification message; and
5 (d) receiving at said at least one communication unit said pending message by said
6 determined reception time.

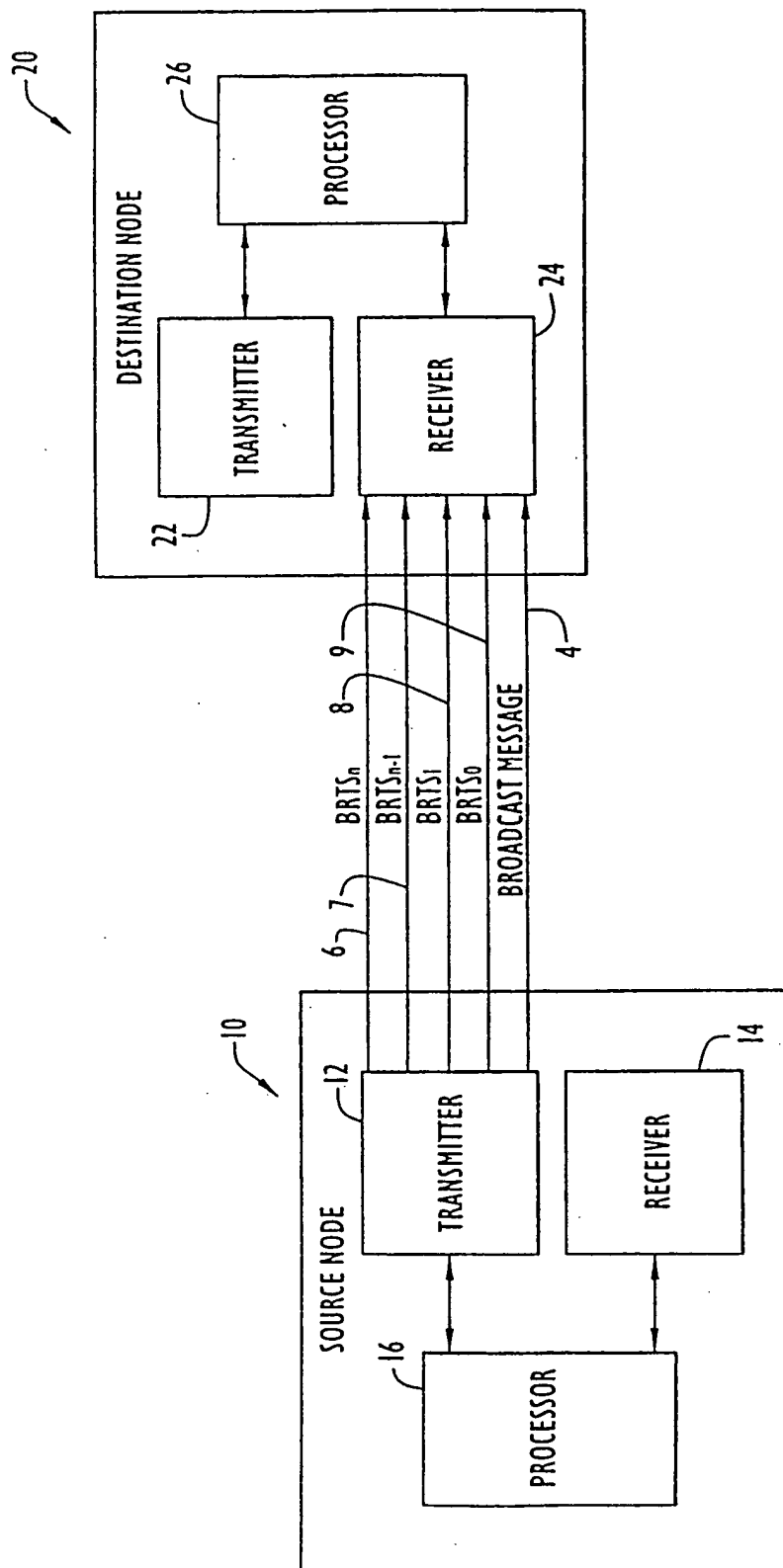


FIG. 1

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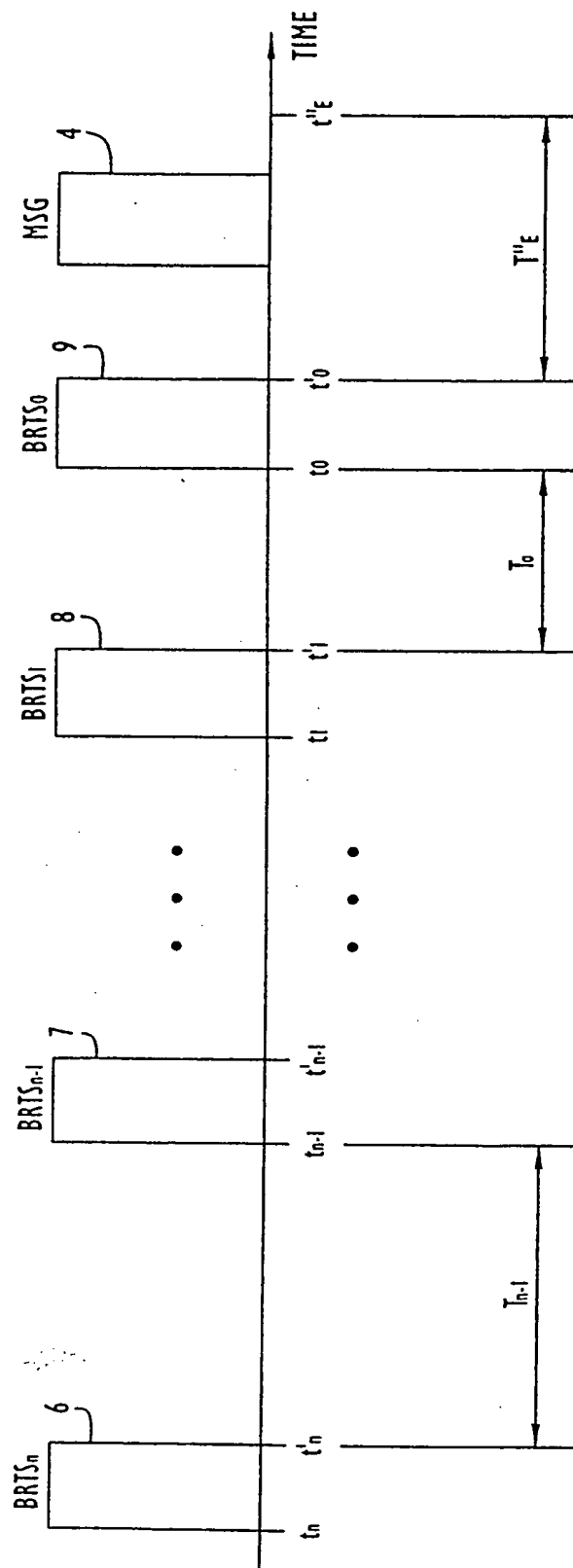


FIG.2

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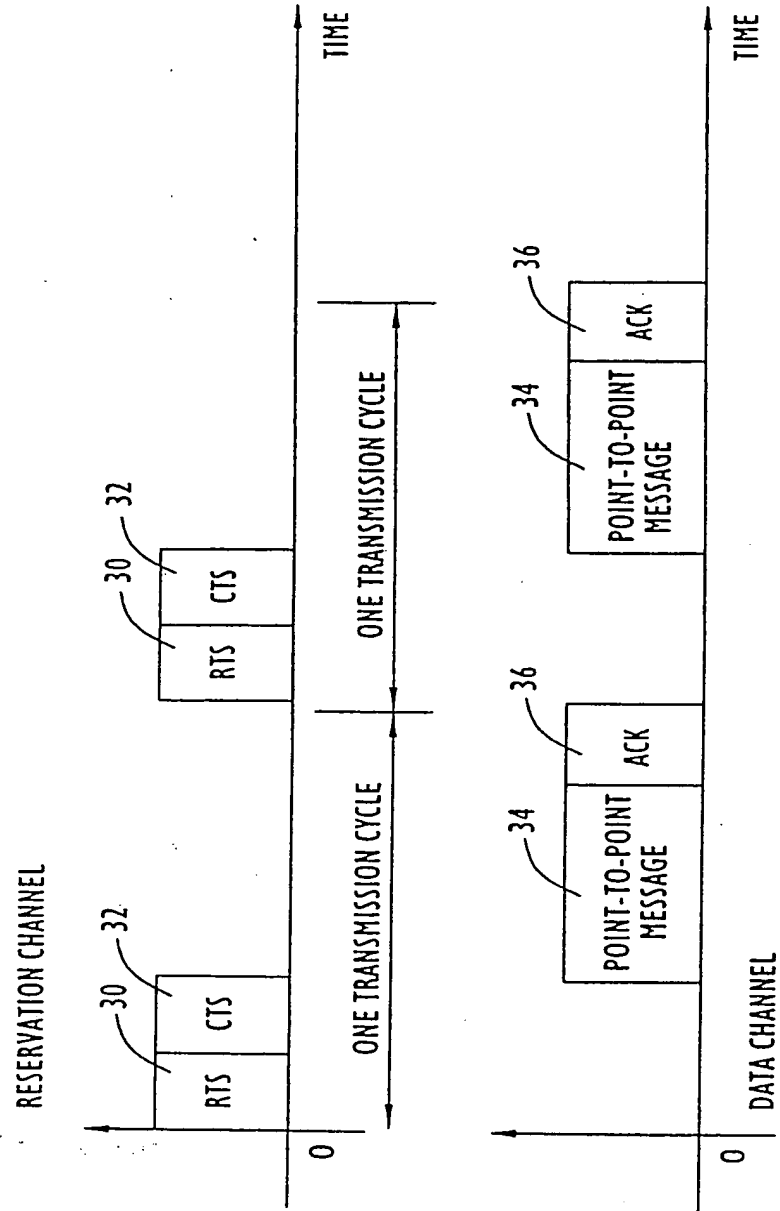


FIG.3

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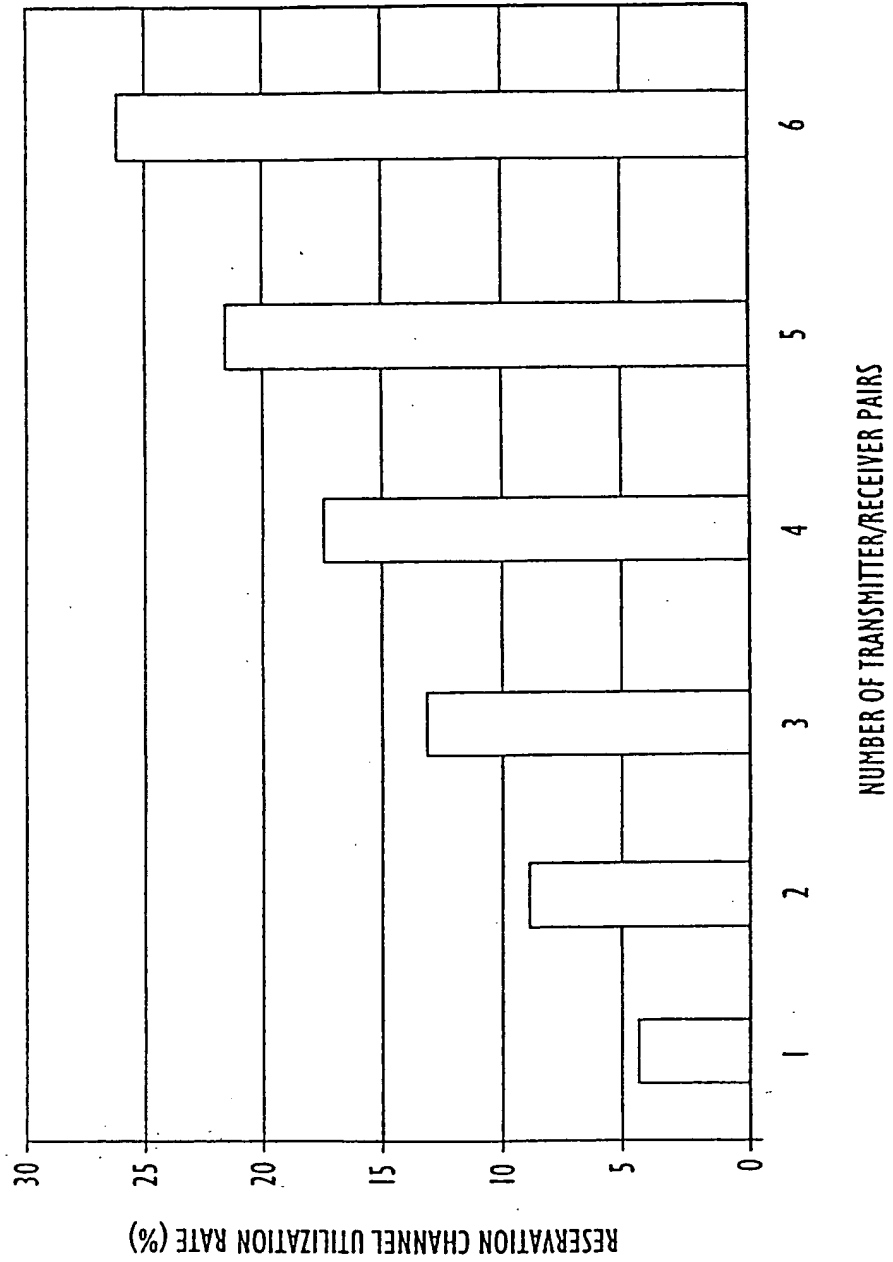


FIG.4

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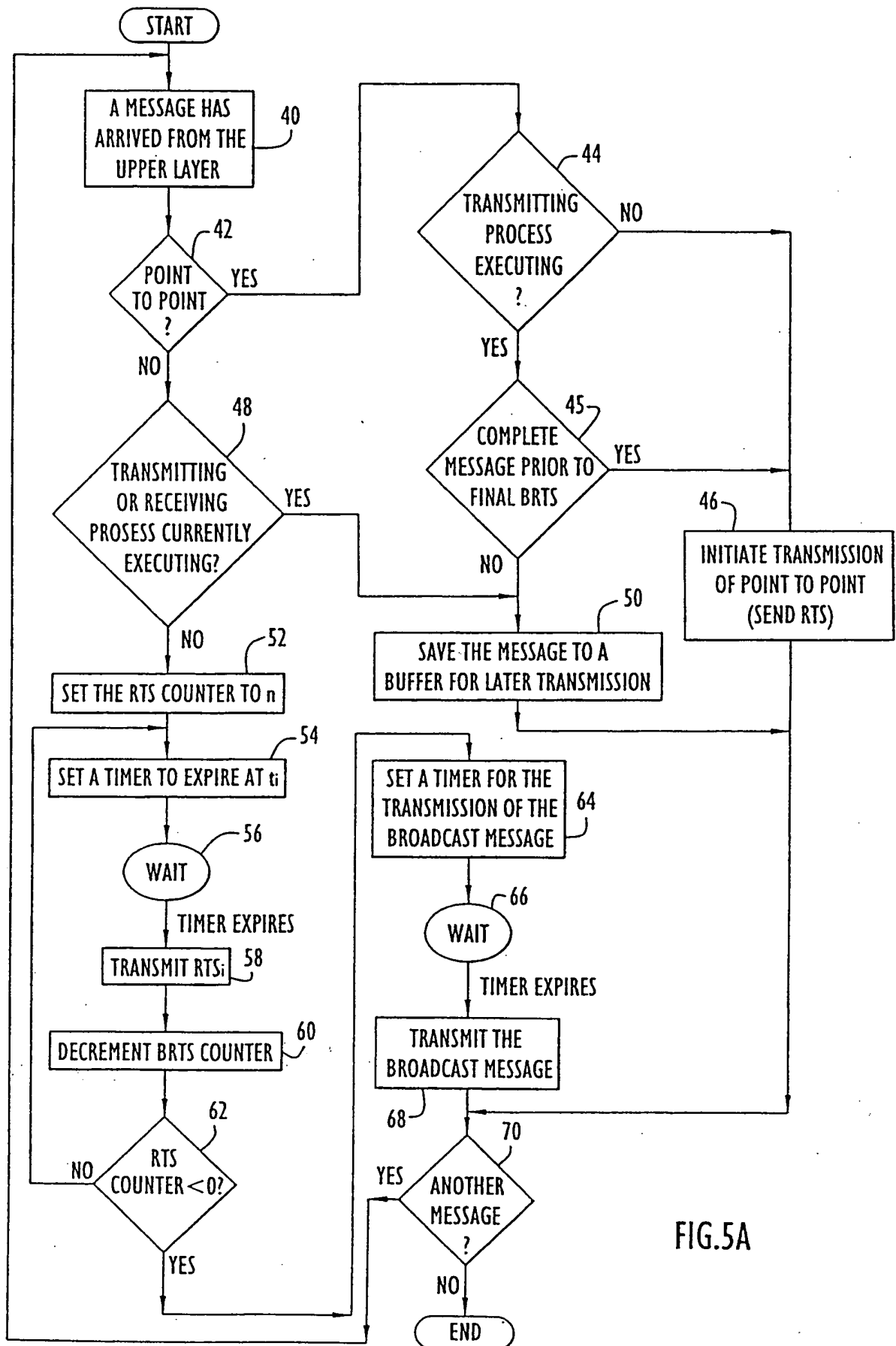
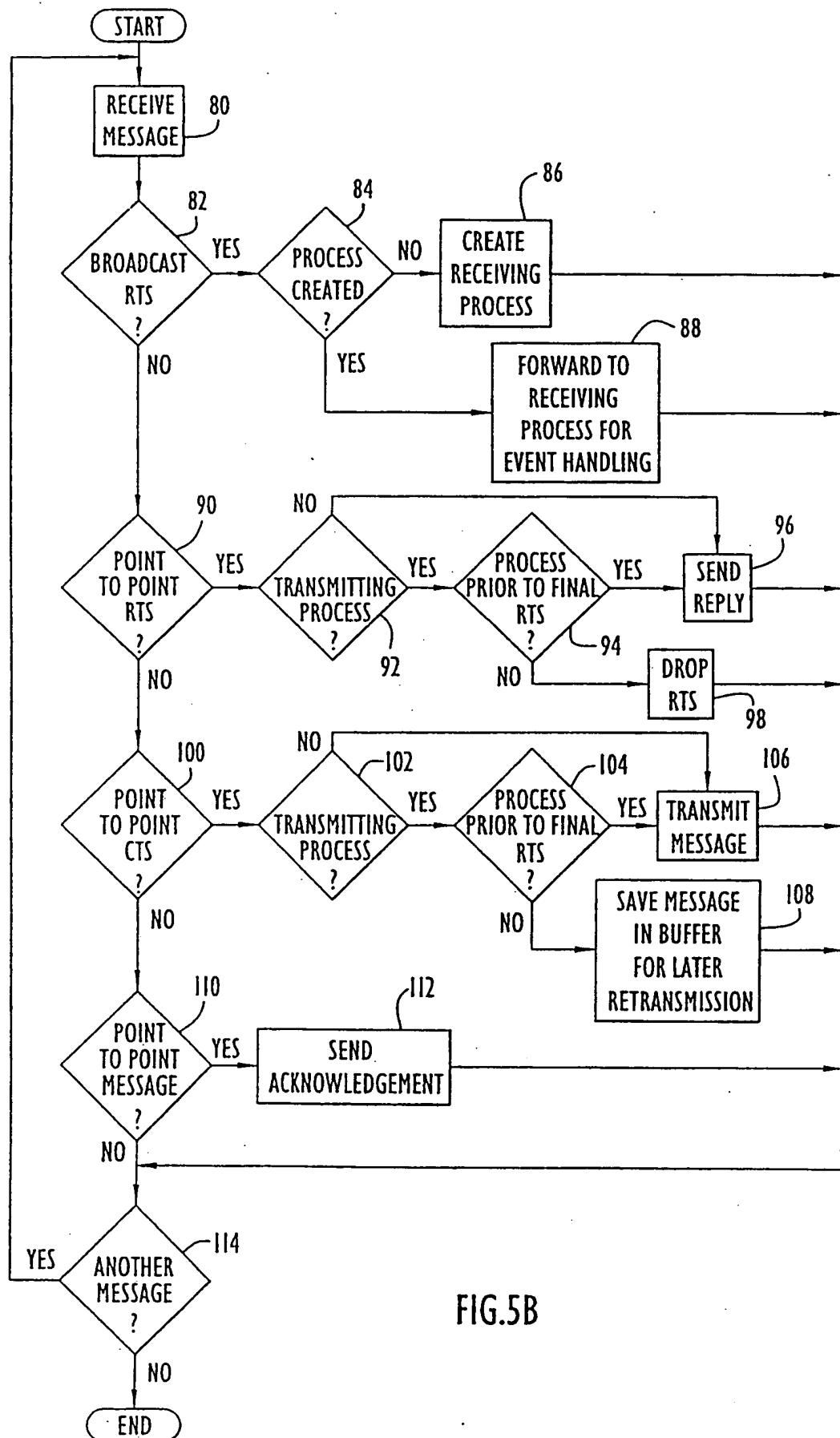


FIG. 5A

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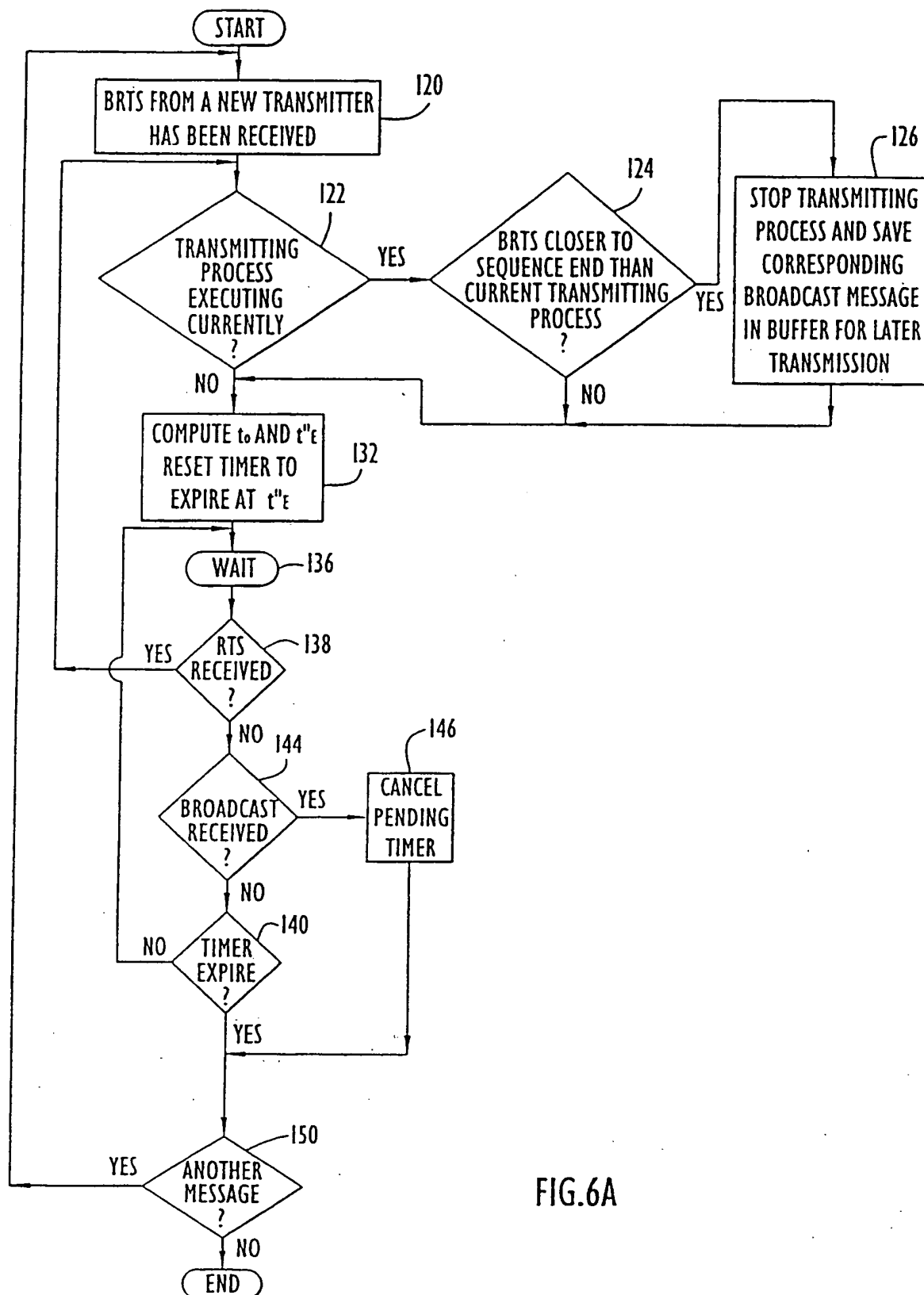


FIG. 6A

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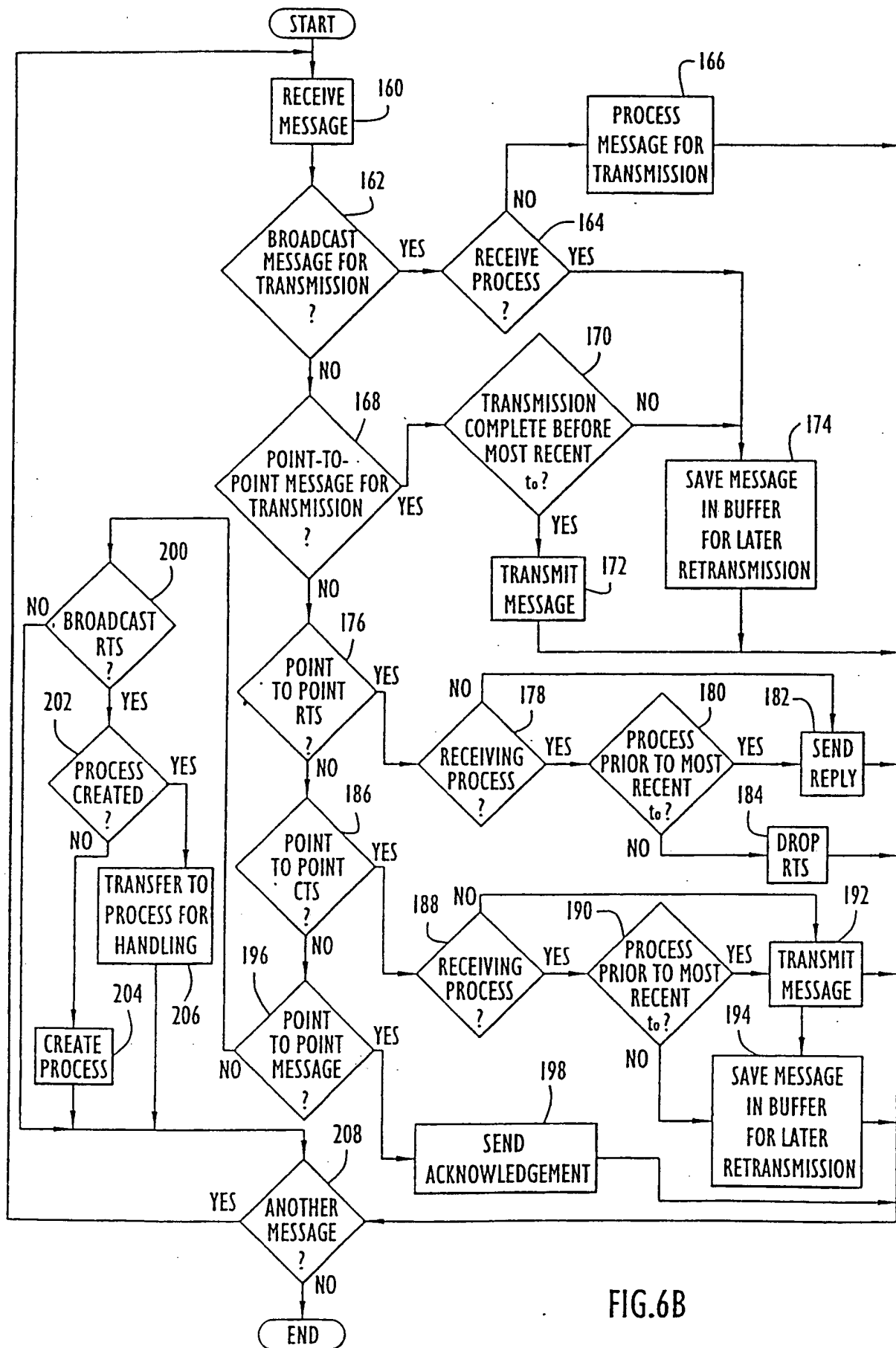


FIG. 6B

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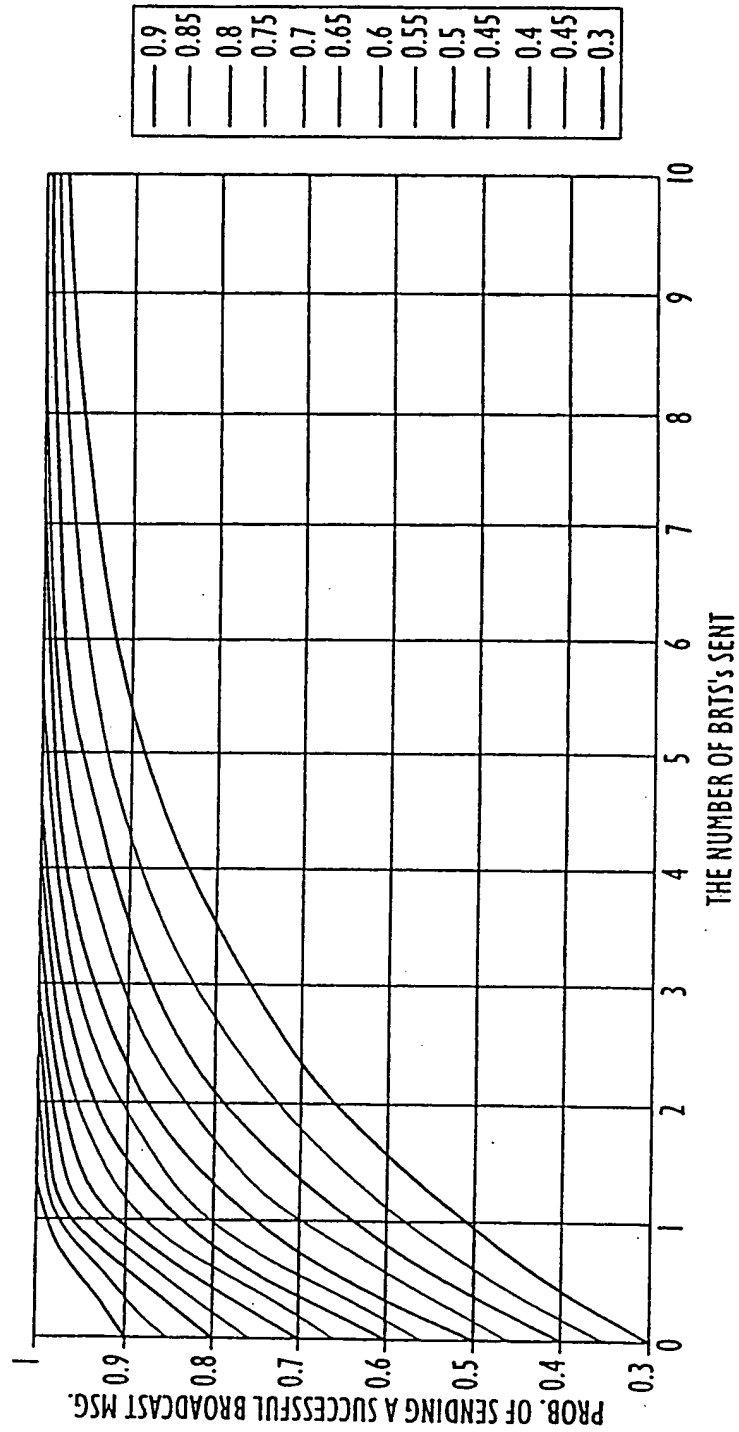
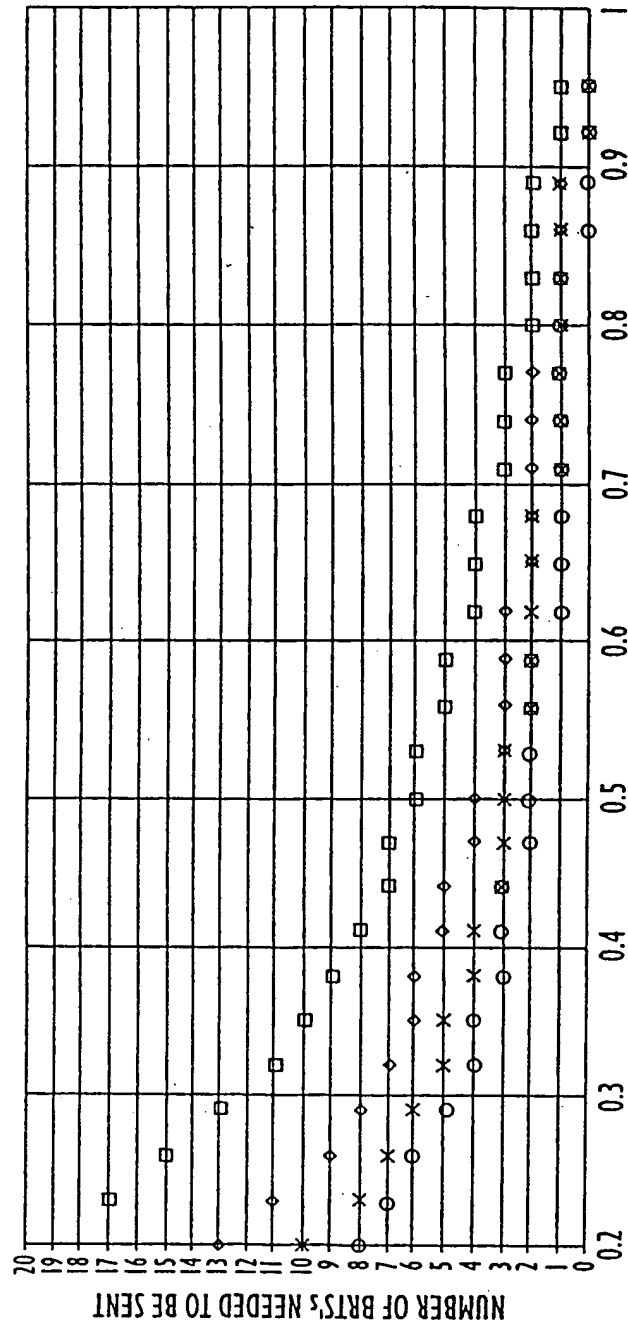


FIG.7

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$\square P_{succ}=0.99$ $\diamond P_{succ}=0.95$ $\times P_{succ}=0.9$ $\circ P_{succ}=0.85$

FIG. 8

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